Year: 2012

The effects of desensitizing resin, resin sealing, and provisional cement on the bond strength of dentin luted with self-adhesive and conventional resincements

Sailer, I ; Oendra, A E H ; Stawarczyk, B ; Hämmerle, C H F

Abstract: STATEMENT OF PROBLEM: Self-adhesive resin cements were designed to bond without any pretreatment of dentin. However, pretreatments such as the application of desensitizing resin or the resin sealing of dentin with priming/bonding solutions might influence the bonding quality of these self-adhesive resin cements. Little is known about the effect of dentin pretreatment on the bond quality of self-adhesive resin cements. PURPOSE: This study evaluated whether dentin desensitizing or sealing methods influenced the shear bond strength of 1 self-adhesive and 2 conventional resin cements. MATERIAL AND METHODS: One-hundred and eighty human molars were assigned to 5 different pretreatment groups: 1) freshly ground dentin, 2) glutaraldehyde/hydroxyethylmethacrylate (HEMA) desensitized dentin (Gluma), 3) contamination of desensitized dentin with provisional cement, 4) sealed dentin (dual bonding technique), and 5) contamination of sealed dentin with provisional cement. The shear bond strength of a self-adhesive resin cement (RelyX Unicem; RXU) and 2 conventional resin cements (Variolink II; VAR, Panavia 21; PAN) was assessed for each pretreatment group (n=12 per cement types). Two-way ANOVA and 1-way ANOVA together with the post hoc Tukey multiple comparison (α=.05) were performed. RESULTS: On freshly ground dentin, PAN exhibited the highest shear bond strength values (P<.001). The use of the glutaraldehyde/HEMA resulted in a significant increase in the bond strength of RXU as compared to fresh dentin (P<.001). Resin sealing of dentin increased the bond strength of RXU but had no significant effect on VAR or PAN. RXU exhibited the highest mean bond strength after the contamination of resin-sealed dentin by provisional cement. CONCLUSIONS: Glutaraldehyde/HEMA treatment and resin sealing of dentin have a beneficial effect on the shear bond strength of self-adhesive resin cement (RXU). Contamination of dentin with provisional cement has no influence on the bond strength of the self-adhesive resin cement (RXU) or VAR but lowered the bond strength of PAN.

DOI: https://doi.org/10.1016/S0022-3913(12)60070-5

Originally published at:
Sailer, I; Oendra, A E H; Stawarczyk, B; Hämmerle, C H F (2012). The effects of desensitizing resin, resin sealing, and provisional cement on the bond strength of dentin luted with self-adhesive and conventional resincements. Journal of Prosthetic Dentistry, 107(4):252-260.
DOI: https://doi.org/10.1016/S0022-3913(12)60070-5

19005

The effects of desensitizing resin, resin sealing, and provisional cement on the bond strength of dentin luted with self-adhesive and conventional resin cements.

ABSTRACT

Statement of the problem. Self-adhesive resin cements were designed to bond without any pretreatment of dentin. However, pretreatments such as the application of desensitizing resin or the resin sealing of dentin with priming/bonding solutions might influence the bonding quality of these self-adhesive resin cements. Little is known about the effect of dentin pretreatment on the bond quality of self-adhesive resin cements.

Purpose. This study evaluated whether or not dentin desensitizing or sealing methods influenced the shear bond strength of 1 self-adhesive and 2 conventional resin cements.

Material and methods. One-hundred and eighty human molars were assigned to 5 different pretreatment groups: 1) freshly ground dentin, 2) Glutaraldehyde/hydroxyethylmethacrylate (HEMA) desensitized dentin (Gluma), 3) contamination of desensitized dentin with provisional cement, 4) sealed dentin (dual bonding technique), and 5) contamination of sealed dentin with provisional cement. The shear bond strength of a self-adhesive resin cement (RelyX Unicem; RXU) and 2 conventional resin cements (Variolink II; VAR, Panavia 21; PAN) was assessed for each pretreatment group (n=12 per cement). Two-way ANOVA and 1-way ANOVA together with post hoc Tukey's test (α= .05) were performed.

Results. On freshly ground dentin, PAN exhibited the highest shear bond strength values ($P<.001$). The use of the glutaraldehyde/HEMA resulted in a significant increase in the bond strength of RXU as compared to fresh dentin ($P<.001$). Resin-sealing of dentin increased the bond strength of RXU but had no significant effect on VAR or PAN. RXU exhibited significantly highest mean bond strength after the contamination of resin-sealed dentin by provisional cement.

Conclusion. Glutaraldehyde/HEMA treatment and resin-sealing of dentin have a beneficial effect on the shear bond strength of self-adhesive resin cement (RXU). Contamination of dentin with provisional cement has no influence on the bond strength of the self-adhesive resin cement (RXU) or VAR but lowered the bond strength of PAN.

Clinical implications. Following tooth preparation, a resin-seal or glutaraldehyde/HEMA treatment of the dentin not only reduces postoperative tooth sensitivity but also improves the bond strength of the self-adhesive resin cement RXU. Therefore, the priming and bonding solutions may have an influence on the adhesive properties of these types of cements.

INTRODUCTION

The establishment of a durable bond between resin cements and human dentin is one of the primary challenges associated with adhesive cementation procedures. Traditional resin cements are hydrophobic. Dentin, however, is a moist, hydrophilic tooth substance.[1-5] Specific multicomponent dentin bonding systems are, therefore, needed to couple traditional resin cements to dentin.[1-5] However, these traditional adhesive cementation techniques are time-consuming and technique-sensitive.[6,7] It is desirable to simplify luting procedures without sacrificing performance.

Several factors might contribute to the differences in dentin bond strength among the cements. It has been shown that the bond strength of resin cements depends, among other factors, on the type and quality of dentin and the preparation depth.[8-11] All bonding agents and resin cements achieve the highest bond strength values on freshly ground, uncontaminated dentin.[12] Yet, after tooth preparation for a fixed restoration, the prepared tooth is still covered with a provisional restoration, which is cemented with provisional cement. The contamination of dentin with provisional cement has been reported to significantly reduce the bond strength values of resin cements to dentin.[13-21] Unfortunately, complete removal of the cement remnants with pumice or a cleaning paste before final cementation is difficult.[14,17,22,23] Remnants of the provisional cements always remain and have been demonstrated to reduce the bond strength of the final resin cements.[13-17,23]

To retain the high bond strengths of freshly ground dentin during the provisional treatment phase, the dual bonding technique for the sealing of dentin was developed.[23] This technique uses the application of a dentin bonding agent to ground dentin directly after tooth preparation and before the cementation of a provisional restoration.[23] Studies showed that resin cements exhibited similar bond strength values on sealed dentin and freshly ground dentin, and that these values were not influenced by the application of provisional cements.[13-25] An additional advantage of the resin-sealing of dentin is a reduction in the hypersensitivity of the abutment tooth after preparation.[26,27] Another method for reducing tooth sensitivity is desensitization of the dentin by means of specific desensitizing primers.[28-31]

Therefore, both methods apply specific primers or bonding agents that may influence the bond strength of traditional resin cements used with bonding agents. While the resin sealing of dentin was documented as beneficial for the bond strength of conventional resin cements,[23-25] conflicting results have been published regarding the influence of dentin desensitization on the bond strength of conventional resin cements.[30-32]

To reduce the general technique-sensitivity of adhesive cementation procedures, self-adhesive resin cements were recently developed.[33, 34] These partly hydrophilic cements are used without any dentin bonding agents, yet exhibit good bond strength values.[33, 34] Since these cements were specifically designed to bond without any pretreatment of the dentin, the desensitization or resin-sealing of dentin might compromise the bonding of self-adhesive resin cements.[27, 35, 36] Little is known about the effect of these types of dentin pretreatments on the bond strength of self-adhesive resin cements.[37-40]

The purpose of the present in vitro study was to test whether or not the shear bond strength of self-adhesive and conventional resin cements was influenced by the resin desensitization or the resin sealing of dentin. The null hypothesis was that pretreatment of dentin with desensitizing resin, resin sealing, and provisional cement have no influence on the shear bond strength of the 2 types of resin cements.

MATERIAL AND METHODS

One self-adhesive resin cement, RXU (RelyX Unicem: 3M ESPE; Seefeld, Germany), and 2 conventional resin cements, VAR (Variolink II: Ivoclar Vivadent; Schaan, Liechtenstein) and PAN (Panavia 21: Kuraray; Okayama, Japan), were included in the study. All resin cements were examined in the chemical polymerization mode. Shear bond strength was measured on freshly ground and on pretreated dentin. The pretreatment was accomplished by sealing the dentin with 1 of 2 bonding agents (Syntac: Ivoclar Vivadent; Schaan, Liechtenstein or Clearfil SE Bond: Kuraray; Okayama, Japan), or by desensitizing the dentin with a glutaraldehyde/HEMA desensitizing primer (Gluma Desensitizer: Heraeus Kulzer; Hanau, Germany). Additionally, the influence of provisional cement (Freegenol: GC International;

Aichi, Japan) was examined. Detailed information on the cements and priming and bonding agents is given in Tables I, II, and III.

A total of 180 extracted human molars, free of caries and restorations, were collected. The teeth were first stored in 0.5% chloramine T solution for up to 7 days, and subsequently in distilled water at 4°C for a maximum of 6 months (ISO 11405). The teeth were cleaned of residual periodontal tissues and were embedded with epoxy resin (Specific Resin 20: Struers; Ballerup, Denmark) in cylindrical mounting cups (MultiForm: Struers; Denmark). After the epoxy resin had set, the specimens were ground flat in a polishing machine (Labopol-21: Struers) with abrasive polishing paper (320 grit: Struers) (ISO 6344). The dentin was exposed to a test surface area of approximately 10 mm^2. The specimens were stored in distilled water at 4°C until needed (ISO/TS 11405). Before the shear bond strength tests, the exposed dentin surface was refreshed in the polishing machine (polishing paper 500 grit, ISO 6344).

The 180 embedded teeth were divided into the following 5 main groups according to the pretreatment of dentin: 1) Group D, freshly ground dentin; Groups DD and DDP, desensitized dentin, and desensitized dentin contaminated with provisional cement, respectively; Groups SD and SDP, sealed dentin (dual bonding technique) and sealed dentin contaminated with provisional cement. Each group, consisting of 36 teeth, was divided into 3 series with 12 teeth. Each series included the combination of 1 cement and 1 pretreatment method (Table IV).

Pretreatment of dentin

For the freshly ground dentin specimens (D), the cements were applied to freshly ground dentin following the manufacturers' instructions (series D-RXU, D-VAR, D-PAN) (Tables I and II). For the desensitized dentin specimens (DD), the dentin was desensitized with a glutaraldehyde/HEMA desensitizing primer (Gluma Desensitizer) according to the manufacturers' instructions (series DD-RXU, DD-VAR, DD-PAN) (Table II). Then, the application of the cements was performed as described for group D. For the contaminated desensitized dentin specimens (DDP), dentin desensitization (Gluma Desensitizer) was first performed, after which provisional cement (Freegenol) was applied (series DDP-RXU, DDP-VAR, DDP-PAN) (Table III). After setting, the provisional cement was removed with an abrasive fluoride-free polishing paste (Cleanic: KerrHawe SA; Bioggio, Switzerland) in combination with a handpiece-driven rubber cup (Table III). The application of the cements was performed as described for group D.

For the sealed dentin specimens (dual bonding technique), the primers were applied to the dentin as in group D. The sealing of the dentin was achieved by an additional application of the corresponding bonding agents (series SD-RXU, SD-PAN: Clearfil SE Bond Bonding, SD-VAR: Heliobond) (Table II). After application, the bonding agents were light polymerized for 10 seconds with an LED polymerization lamp (Elipar Freelight 2: 3M ESPE; Seefeld, Germany) (light intensity 1200 mW/cm2, curing distance approx. 5 mm). After the polymerization of the bonding agents, the resin-sealed surfaces were polished with the polishing paste (Cleanic) and the rubber cup to remove the oxygen-inhibited surface. The application of the cements was performed as described for group D.

For the contaminated resin-sealed dentin specimens (series SDP-RXU, SDP-VAR, SDP-PAN), the resin-sealing of the dentin was performed as described for group SD. Subsequently, the provisional cement was applied and removed after setting as in group DDP. The application of the cements occurred as described for group D.

Application of the cement

Before the application of the cement, each specimen was fixed in a custom-made bonding device (Fig.1a and b) with the pretreated dentin surface facing upwards. A hollow, clear acrylic resin cylinder (D + R Tec; Birmensdorf, Switzerland) with an inner diameter of 3.0 mm was fixed perpendicularly to the dentin surface by means of a holder in the bonding device. The cylinder was filled with the corresponding resin cement. To ensure that the cement was adapted to the dentin surface, a screw was fixed to a custom-made device inserted centrally into the cylinder and perpendicular to the dentin surface. The distance of the screw head to the dentin surface was set at 1 mm (Fig. 1b). In this procedure, the resulting cement layer was standardized to a thickness of 1 mm. A load of 1 N was applied to the screw and the cement excess was carefully removed. The cement was allowed to set under the constant load of 1 N. After 10 minutes setting time in a 37°C incubator (EG 240: Binder; Tuttlingen, Germany), the specimen was removed from the bonding device.

Shear bond strength measurement

The test specimens underwent the following aging steps directly after chemical polymerization of the resin cements: 1) 24 hours of water storage at 37°C in an incubator (EG 240: Binder; Tuttlingen, Germany), 2) 1,500 cycles of thermocycling (5°C/55°C, transfer time 10 seconds, dwell time 20 seconds; Thermocycler Willytec; Feldkirchen-Westerham, Germany), and 3) 1 hour of water storage at room temperature.

After the aging procedure, the shear bond strength was measured with a universal testing machine (Z010 Zwick: Zwick/Roell; Ulm, Germany). The specimens were positioned in a custom-made specimen holder with the dentin surface parallel to a loading piston with a chisel-like configuration. The load was then applied to the cylinder with a crosshead speed of 1 mm per minute (ISO/TS 11405) until debonding occurred.

The debonded surfaces were examined with a binocular microscope (Wild; Heerbrugg, Switzerland) at ×25 magnification in order to determine the mode of the debonding. The debonding types were classified as adhesive fracture (no cement remnants identifiable on the dentin surface) or cohesive fracture (dentin surface completely covered with cement). In the case of a mixed fracture type within 1 specimen (cement remnants as well as exposed dentin areas identifiable), the respective specimen was assigned to the predominant fracture type. All fracture types were assessed by 1 trained operator.

Mean values and standard deviations were determined for each group. In each test series, the 2 measured values with the largest discrepancy from the average value were excluded from the statistical analysis. The values were then ranked from the highest to the lowest for all groups, and then compared with respect to the factors "cement" and "pre-treatment method" (i.e. series). The comparison of the series was performed with 2-way ANOVA and 1-way ANOVA followed a post hoc Tukey's multiple comparison tests (SPSS 16.0: SPSS Inc.; Chicago, Ill), using rank transformed data according to Conover and Iman[41]. The level of statistical significance was set at $p<.05$.

RESULTS

Table V presents the descriptive statistics of all test groups. The results of 2-way ANOVA showed the significant impact of dentin pretreatment ($P<.001$), choice of resin cement ($P<.001$), and the interaction between dentin pretreatment and resin cement ($P<.001$) (Table VI) on shear bond strength.

On freshly ground dentin (group D), PAN (D-PAN) exhibited the highest mean bond strength values ($P<.001$). The mean bond strength value of this cement was significantly higher

(P<.001) than that of either RXU (D-RXU) or VAR (D-VAR), neither of which were different from each other (Table V).

After the glutaraldehyde/HEMA desensitization of dentin in group DD the mean bond strength value of RXU (DD-RXU) was similar to the mean bond strength value of PAN (DD-PAN). The dentin bond strength of these 2 resin cements was significantly higher than that of VAR (DD-VAR) (P<.001) (Table V), which was unaffected by glutaraldehyde/HEMA pretreatments. In Group DDP, contamination of the glutaraldehyde/HEMA desensitized dentin with provisional cement (DDP-RXU, DDP-VAR, DDP-PAN) did not result in significant change of the bond strength values of the 3 cements. That is, RXU (DDP-RXU) and PAN (DDP-PAN) exhibited significantly higher bond strength values than VAR (DDP-VAR) (P<.001) (Table V). The bond strength values of VAR (DD-VAR, DDP-VAR) remained low regardless of pretreatments (Table V).

After the resin-sealing of dentin with Clearfil SE Bond (for RXU and PAN cements) or Heliobond for VAR cement, (groups SD and SDP), PAN (SD-PAN) exhibited the highest dentin bond strength of all 3 cements (SD-PAN vs. SD-RXU; P<.05, SD-PAN vs. SD-VAR; P<.001). No difference was found between the mean bond strength values of RXU and VAR (Table V). The sealing of the dentin led to an increase in the bond strength of RXU and VAR as compared to freshly ground dentin (SD-RXU vs. D-RXU; P<.05, SD-VAR vs. D-VAR; P<.001). No significant differences were found in PAN bond strengths when resin-sealed dentin was compared to control group dentin, or any other pretreatment. (Table V).

The contamination of resin-sealed dentin with provisional cement (group SDP) did not affect the dentin bond strength of RXU (SDP-RXU). RXU exhibited significantly higher mean bond strength values than VAR or PAN (P<.001) (Table V). With the use of VAR and PAN, a decrease of the bond strength was generally observed after provisional cement was applied to the resin-sealed dentin. For PAN, a significant drop in bond strength after the application of provisional cement occurred (SD-PAN vs. SDP-PAN; $P<0.001$) (Table V).

Within the debonding failure types, microscopic analysis of the tested specimens bonded with RXU showed predominantly cohesive fracture in all series (Fig. 2). This indicates that the cement itself was the weakest link. Among the specimens luted with VAR, predominantly adhesive fractures were found. In all series, the fractures were located predominantly at the bonding interface, with one exception; on resin-sealed and subsequently contaminated dentin, cohesive fractures prevailed (Fig. 3). The analysis of the specimens bonded with PAN displayed a homogenous result of 100% with adhesive failures occurring in all series (Fig. 4).

DISCUSSION

The null-hypothesis that bond strength values of self-adhesive and conventional resin cements to dentin are not influenced by desensitizing dentin, resin sealing, or the application of a provisional cement was rejected. The type of influence of the pretreatments on the bond strength varied, however, among the cements.

The conventional resin cement PAN exhibited the highest bond strength values of all tested cements on freshly ground dentin. These high bond strength values were not influenced by the pretreatment of the dentin with glutaraldehyde/HEMA desensitizer or by resin-sealing the dentin. However, the application of provisional cement had a negative influence on the bond strength values. The bond strength of PAN on sealed dentin dropped significantly after the application of provisional cement.

For the self-adhesive resin cement RXU, there was a beneficial effect on the bond strength of both desensitization and resin sealing. The bond strength of RXU was significantly increased with the application of glutaraldehyde/HEMA desensitizer and resin-sealing; in the case of the former, even approaching the bond strength values of PAN. Furthermore, for this cement no influence of the provisional cement on the bond strength was found. The bond strength values of RXU were not reduced when either the desensitized or the resin-sealed dentin was contaminated with provisional cement.

The pretreatment of the dentin also exhibited an influence on the bond strength of VAR. In general, the resin cement VAR exhibited the lowest bond strength values of all 3 cements. These bond strength values were even lower than the values on freshly ground dentin after glutaraldehyde/HEMA desensitization. Only resin-sealing with Heliobond exhibited a beneficial influence on VAR. The application of the provisional cement exhibited no influence on the bond strength for this cement.

The finding that the bonding capacity of PAN to freshly ground dentin was significantly better than either of the other 2 cements is in agreement with other studies reporting on the bond strength of PAN to freshly ground dentin.[38,39] In contrast, the self-adhesive resin cement RXU only exhibited one-third of the bond strength of PAN. In a similar study comparing the bond strength of PAN and RXU to freshly ground dentin, using the same experimental design as the present study, similar observations were made.[37] One reason for these differences might be that conventional resin cements are used in combination with pretreatment priming and bonding solutions, whereas self-adhesive resin cements are directly applied to the dentin.

It has been stated that the bond strength of resin cements depends on, among other factors, the type of dentin (coronal vs apical), the preparation depth (superficial vs close to the pulp), and the age of the patient.[8-11, 40] These investigations show that the quality of the dentin surface itself is crucial in the bonding outcome. When using self-adhesive resin cements, no conditioning of the dentin with a bonding agent is needed. This type of cement is partly hydrophilic and bonds directly to the wet dentin surface. Therefore, RXU might be even more dependent on the quality and type of the dentin than traditional resin cements that are used with a bonding agent.[37] The highly varying bond strength values of RXU to dentin have been published in other studies using similar methods to those of the present study.[34,39] Higher bond strength values for RXU up to 12.9 MPa were found in a comparable study.[39] A direct comparison of the values of these studies, however, is critical. It should be noted that small differences in the test procedures of bond strength tests results in high variations in the obtained bond strength values. More studies using a standardized test method are needed to confirm the previously reported observations.

The factors influencing the bond strength of resin cements are mostly related to the bonding mechanism between resin cement and dentin. These factors might be influenced by chemical changes to the dentin surface. It has been shown that the bond strength of resin cements can be improved with the application of HEMA- and glutaraldehyde-containing desensitizing primers.[35,36] The desensitizing primers cause the formation of a collagen-glutaraldehyde complex at the primer-dentin interface. Subsequently, a chemical bond between the HEMA molecules in the primer and this collagen-glutaraldehyde complex occurs. Finally, a copolymerization of the resin cement and the bound HEMA groups occurs and may improve the bond strength of the resin cement.[35,36]

It is assumed, that these chemical factors are related to the increase in the bond strength of the self-adhesive resin cement RXU in combination with the HEMA- and glutaraldehyde-containing desensitizing primer Gluma that was observed in the present as well as in a previous study.[37] Yet in the investigations of the interactions between Gluma and the dentin, the smear layer was removed, and the dentin was demineralized by the application of EDTA before the application of the desensitizer.[35,36] In the present study, the bond strength was tested to mineralized dentin covered with a smear layer. It has been shown that the glutaraldehyde in Gluma cannot cross-link mineralized dentin.[35] Therefore, a chemical mechanism seems unlikely to be the reason for the increase in the bond strength of RXU. It is more likely that the HEMA component in Gluma has a significant role. It can be assumed that the HEMA pretreated dentin surface allows the resin cement to better wet the dentin surface and therefore, results in an increase in bond strength.

To fully understand the present observations, more studies testing the mechanisms leading to the increase in bond strength of RXU are needed. The interactions of glutaraldehyde/ HEMA desensitizer, mineralized dentin, and the self-adhesive resin cement RXU need to be studied in more detail. This is a limitation of the present study, and future experiments should focus on the debonding failure types of the tested specimens in more detail. SEM analyses of the debonded surfaces should be performed to determine whether a residual smear layer is present, or whether the self-adhesive resin cement enters the dentin beneath the smear layer.

Finally, the pretreatment of the dentin (desensitization, sealing) reduced the effect of contamination with provisional cement. In most of the tested groups (RXU, VAR, PAN), no decrease of the mean bond strength values was found after contamination of the desensitized or sealed dentin with provisional cement. More interestingly, the self-adhesive resin cement RXU exhibited high bond strength values for the pretreated dentin, regardless of contamination with provisional cement. The bond strength of PAN, however, dropped after contamination of the sealed dentin with provisional cement. RXU might, therefore, be considered more predictable and less technique-sensitive than the traditional resin cement PAN. Again, additional research is needed to support this observation and to analyze the reasons for this promising observation.

CONCLUSIONS

The application of glutaraldehyde/HEMA and the resin-sealing of dentin had a beneficial effect on the bond strength of the self-adhesive resin cement RXU. Furthermore, the application of provisional cement before adhesive cementation did not significantly influence the bond strength of the self-adhesive resin cement RXU. This type of self-adhesive cement might, therefore, be considered more predictable and less technique-sensitive than the conventional resin cements applied with bonding agents.

REFERENCES

1. Mitchem JC, Gronas DG. Adhesion to dentin with and without smear layer under varying degrees of wetness. J Prosthet Dent 1991;66:619-22.

2. Edelhoff D, Özcan M. To what extent does the longevity of fixed dental prostheses depend on the function of the cement? Working Group 4 materials: cementation. Clin Oral Implants Res 2007; 18 (Suppl 3):193-204.

3. Moll K, Haller B. Effect of intrinsic and extrinsic moisture on bond strength to dentine. J Oral Rehabil 2000;27:150-65.

4. Ferrari M, Tay FR. Technique sensitivity in bonding to vital, acid-etched dentin. Oper Dent 2003;28:3-8.

5. Jacobsen T. Bonding of resin to dentin. Interactions between materials, substrate and operators. Swed Dent J Suppl 2003;160:1-66.

6. Frankenberger R, Kraemer N, Petschelt A. Technique sensitivity of dentin bonding: Effect of application mistakes on bond strength and marginal adaptation. Oper Dent 2000;25:324-30.

7. Inoue S, Vargas MA, Abe Y, Yoshida Y, Lambrechts P, Vanherle G et al. Microtensile bond strength of eleven contemporary adhesives to dentin. J Adhesive Dent 2001;3:237-245.

8. Pashley DH. In vitro simulations of in vivo bonding conditions. Am J Dent 1991;4:237-40.

9. Øilo G. Bond strength testing – what does it mean? Int Dent J 1993;43:493-8.

10. Paul SJ, Schaerer P. Factors in dentin bonding. Part I: A review of the morphology and physiology of human dentin. J Esthet Dent 1993;5:5-8.

11. Paul SJ, Schaerer P. Factors in dentin bonding. Part II: A review of the morphology and physiology of human dentin. J Esthet Dent 1993;5:51-4.

12. Magne P, So WS, Cascione D. Immediate dentin sealing supports delayed restoration placement. J Prosthet Dent 2007;98:166-74.

13. Hansen EK, Asmussen E. Influence of temporary filling materials on effect of dentin-bonding agents. Scand J Dent Res 1987;95:516-20.

14. Woody TL, Davis RD. The effect of eugenol-containing and eugenol-free temporary cements on microleakage in resin bonded restorations. Oper Dent 1992;17:175-80.

15. Powers JM, Finger WJ, Xie J. Bonding of composite resin to contaminated human enamel and dentin. J Prosthodont 1995;4:28-32.

16. Bachmann M, Paul SJ, Luethy H, Schaerer P. Effect of cleaning dentine with soap and pumice on shear bond strength of dentine-bonding agents. J Oral Rehabil 1997;24:433-8.

17. Paul SJ, Schaerer P. Effect of provisional cements on the bond strength of various adhesive bonding systems on dentine. J Oral Rehabil 1997;24:8-14.

18. Abdalla AI, Davidson CL. Bonding efficiency and interfacial morphology of one-bottle adhesives to contaminated dentin surfaces. Am J Dent 1998;11:281-5.

19. Van Schalkwyk JH, Botha FS, Van Der Vyver PJ, De Wet FA, Botha SJ. Effect of biological contamination on dentine bond strength of adhesive resins. SADJ 2003;58:143-7.

20. Sattabanasuk V, Shimada Y, Tagami J. Effects of saliva contamination on dentin bond strength using all-in-one adhesives. J Adhes Dent 2006;8:311-8.

21. Yoo HM, Pereira PN. Effect of blood contamination with 1-step self-etching adhesives on microtensile bond strength to dentin. Oper Dent 2006;31:660-5.

22. Schwartz R, Davis R, Hilton TJ. Effect of temporary cements on the bond strength of a resin cement. Am J Dent 1992;5:147-50.

23. Paul SJ, Schärer P. The Dual Bonding Technique: A modified method to improve adhesive luting procedures. Int J Periodont Rest Dent 1997;17:537-45.

24. Bertschinger CH, Paul SJ, Luethy H, Schaerer P. Dual application of dentin bonding agents: Effect on bond strength. Am J Dent 1996;9:115-9.

25. Martin R, Paul SJ, Luethy H, Schaerer P. Dentin bond strength of Dyract Cem. Am J Dent 1997;10: 27-31.

26. Braennstroem M. Sensitivity of dentine. Oral Surg 1966;21:517-26.

27. Braennstroem M, Aastrom A. The hydrodynamics of the dentin; its possible relationship to dentinal pain. Int Dent J 1972;22:219-27.

28. Schupach P, Lutz F, Finger WJ. Closing of dentinal tubules by Gluma desensitizer. Eur J Oral Sciences 1997;105: 414-21.

29. Kolker JL, Vargas MA, Armstrong SR, Dawson DV. Effects of desensitizing agents on dentin permeability and dentin tubule occlusion. J Adhes Dent 2002;4: 211-21.

30. Reinhardt JW, Stephens NH, Fortin D. Effect of Gluma desensitization on dentin bond strength. Am J Dent 1995;8:170-2.

31. Cobb DS, Reinhardt JW , Vargas MA. Effect of HEMA-containing dentin desensitizers on shear bond strength of a resin cement. Am J Dent 1997;10:62-5.

32. Yim NH, Rueggeberg FA, Caughman WF, Gardner FM, Pashley DH. Effect of dentin desensitizers and cementing agents on retention of full crowns using standardized crown preparations. J Prosthet Dent 2000;83:459-65.

33. De Munck J, Vargas M, Van Landuyt K, Hikita K, Lamprechts P, Van Meerbeck B. Bonding of an auto-adhesive luting material to enamel and dentin. Dent Mater 2004;20:963-71.

34. Abo-Hamar SE, Hiller KA, Jung H, Federlin M, Friedl KH, Schmalz G. Bond strength of a new universal self-adhesive resin luting cement to dentin and enamel. Clin Oral Invest 2005;9:161-7.

35. Qiu C, Xu J, Zang Y. Spectroscopic investigation of the function of aqueous 2-hydroxyethylmethacrylate/glutaraldehyde solution as a dentin desensitizer. Eur J Oral Sci 2006;114:354-359.

36. Munksgaard EC, Asmussen E. Bond strength between dentin and restorative resin mediated by mixtures of HEMA and glutaraldehyde. J Dent Res 1984;63:1087-9

37. Sailer I, Tettamanti S, Stawarczyk B, Haemmerle CH. In-vitro study of the influence of various dentin sealing and desensitizing methods on the shear bond strength of two universal resin cements. J Adhes Dent 2010;12:381-92

38. Stewart GP, Jain P, Hodges J. Shear bond strength of resin cements to both ceramic and dentin. J Prosthet Dent 2002;88:277-84.

39. Holderegger C, Sailer I, Schuhmacher C, Schläpfer R, Haemmerle CH, Fischer J. Shear bond strength of resin cements to human dentin. Dent Mater 2008;24:944-50.

40. Yang B, Ludwig K, Adelung R, Kern M. Micro-tensile bond strength of three luting resins to human regional dentin. Dent Mater 2006;22:45-56.

41. Conover WJ, Iman RL. Analysis of covariance using the rank transformation. Biometrics 1982;38: 715-724.

Table I. Composition of resin cements

Name (short name)	Composition	
RelyX Unicem (RXU)	Powder	Silanized glass powder, initiator, silanized silicic acid, substituted pyrimidine, calcium hydroxide, peroxo-compound, pigment
	Liquid	Methacrylated phosphoric ester, dimethacrylate, acetate, stabilizer, initiator
Variolink II (VAR)	Matrix	Bis-GMA, UDMA, TEGDMA
	Anorganic fillers	Barium glass, ytterbium fluoride, Ba-Al-Fluor silicate glass, spheroid mixed oxide, catalysts, stabilizers, pigments
Panavia 21 (PAN)	Base	Comonomers, amines, fillers, initiator
	Catalyst	MDP, comonomers, fillers, benzoyl peroxide

Bis-GMA, 2-bis-phenol A diglycidyl methacrylate; UDMA, Urethane dimethacrylate: TEGDMA, Triethyleneglycol dimethacrylate; MDP, 10-methacrylate oxydecyl dihydrogen phosphate

Table II. Composition of dentin bonding agents and desensitizers.

Name	Purpose	Composition
Syntac	Light-polymerizing, 2-phase adhesive system (for use with light- and auto-polymerizing composite resins)	Primer: Polyethylene glycol dimethacrylate, maleic acid, ketone (acetone), water Adhesive: Polyethylene glycol dimethacrylate, glutaraldehyde, water Heliobond: Bis-GMA, triethylene glycol dimethacrylate
Clearfil SE Bond	Light-polymerizing adhesive system	Primer: MDP, HEMA, hydrophilic dimethacrylate, dl-camphor-quinine, N,N-diethanol-p-toluidine, water Bond: MDP, bis-GMA, HEMA, hydrophilic dimethacrylate, dl-camphor-quinine, N,N-diethanol-p-toluidine, colloidal silicon oxide
ED Primer	Priming solution (for use with Panavia)	Primer A: HEMA, MDP, MASA, activator, water Primer B: MASA, activator, water
Gluma Desensitizer	Treatment of hypersensitive dentin	HEMA (25-50%), glutaraldehyde (5-10%), distilled water

Bis-GMA, 2-bis-phenol A diglycidyl methacrylate; MDP - 10-methacrylate oxydecyl dihydrogen phosphate; HEMA, 2-hydroxyethyl methacrylate; MASA, N-methacryloyl-5-aminosalicylic acid.

Table III. Composition of provisional cement and cleaning paste.

Name	Purpose	Composition
Freegenol	Auto-polymerizing eugenol-free provisional cement	Zinc oxide 40.7%, olive oil 11.55%, colophony glycerol ester (rosin) 10.4%, oleic acid 5.6%, pelargonic acid 3.4%
Cleanic (Art. Nr. 3210)	Universal prophylaxis paste with cleaning and polishing effect	Silicates, humectant, binder, diluents, flavors (peppermint, menthol), colorants (E 132, titanium dioxide)

Table IV. Overview of experimental groups and series.

Dentin	Group	Series	Sealing/Desens.	Provisional Cement	Adhesive system	Resin Cement
freshly ground	D	RXU	Ø	Ø	Ø	RelyX
		VAR	Ø	Ø	Syntac P+A	Variolink II
		PAN	Ø	Ø	ED Primer	Panavia 21
desensitized	DD	RXU	Gluma	Ø	Ø	RelyX
		VAR	Gluma	Ø	Syntac P+A	Variolink II
		PAN	Gluma	Ø	ED Primer	Panavia 21
desensitized + provisional	DDP	RXU	Gluma	Freegenol	Ø	RelyX
		VAR	Gluma	Freegenol	Syntac P+A	Variolink II
		PAN	Gluma	Freegenol	ED Primer	Panavia 21
sealed	SD	RXU	Clearfil SE Bond	Ø	Ø	RelyX
		VAR	Syntac P+A+B	Ø	Syntac P+A	Variolink II
		PAN	Clearfil SE Bond	Ø	Clearfil SE	Panavia 21
sealed + provisional	SDP	RXU	Clearfil SE Bond	Freegenol	Ø	RelyX
		VAR	Syntac P+A+B	Freegenol	Syntac P+A	Variolink II
		PAN	Clearfil SE Bond	Freegenol	Clearfil SE	Panavia 21

P = Primer, A = Adhesive, B = Bonding;

Table V. Summary of effects of various pretreatments on shear bond strength (MPa) of 3 luting cements (mean value ± SD (n = 12).

		RXU	**VAR**	**PAN**
D	**freshly ground dentin**	5.5 ± 2.0 $^{a\,B}$	3.9 ± 2.4 $^{b\,A}$	16.3 ± 3.5 ^{bc}
DD	**desensitized dentin**	17.1 ± 5.3 $^{b\,B}$	1.1 ± 0.8 $^{a\,A}$	18.2 ± 4.5 $^{b\,B}$
DDP	**desensitized dentin + contamination**	14.3 ± 5.9 $^{b\,B}$	0.2 ± 0.5 $^{a\,A}$	16.1 ± 2.2 $^{b\,B}$
SD	**sealed dentin**	12.3 ± 3.6 $^{b\,A}$	9.1 ± 4.5 $^{c\,A}$	19.9 ± 6.7 $^{b\,B}$
SDP	**sealed dentin + contamination**	15.4 ± 3.3 $^{b\,B}$	7.6 ± 2.2 $^{c\,A}$	5.6 ± 2.7 $^{a\,A}$

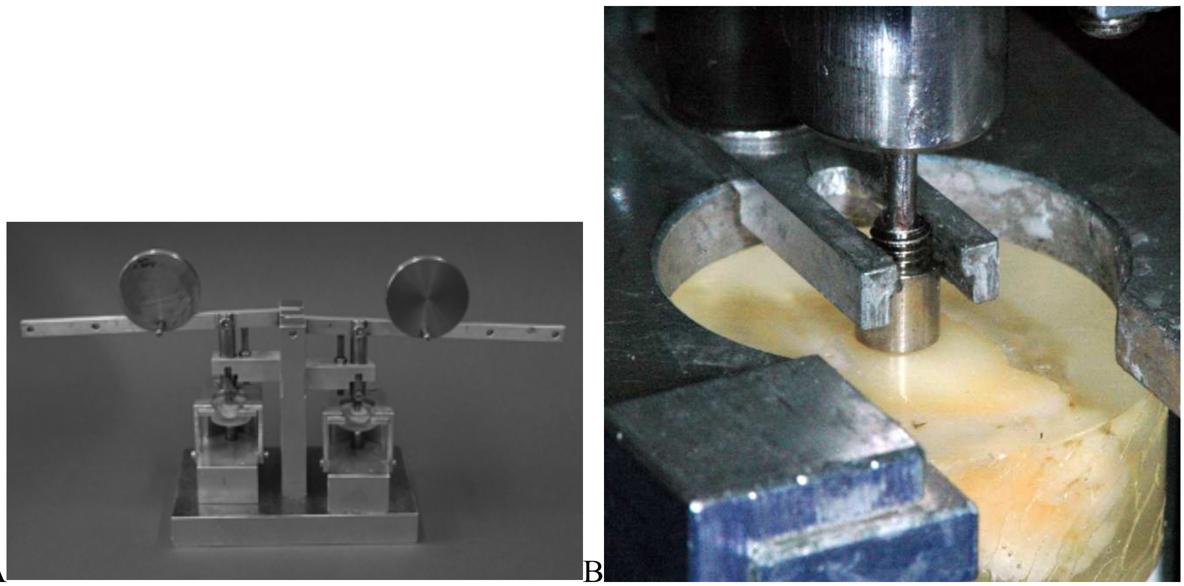
Groups identified by different superscript lower case letters are significantly different (P<.01). Lower case letters indicate statistical different influences of the pretreatment at the respective cement. Upper case letters show statistical differences of bond strength values of cements after the respective dentin pretreatment.

Table VI. Two-way ANOVA results using rank transformed data for comparison of shear bond strength after different dentin preparation and application of different cements.

	Sum of Squares	df	Mean Squares	F	P
Dentin preparation	52280	4	13070	35.3	<.001
Cement	92352	2	46176	124.9	<.001
Dentin preparation × cement	86683	8	10835	29.3	<.001
Error	49923	135	370		
Total	1136275	150			

LEGENDS

Fig.1A Custom-made bonding device enabling bonding of 2 specimens B. Detailed view of bonding device, accomplishing standardized thickness of resin cement of 1 mm by means of screw applying pressure to cement



A B

Fig.2. Debonding mode of specimens bonded with RelyX Unicem (Series consisting of 12 specimens each).

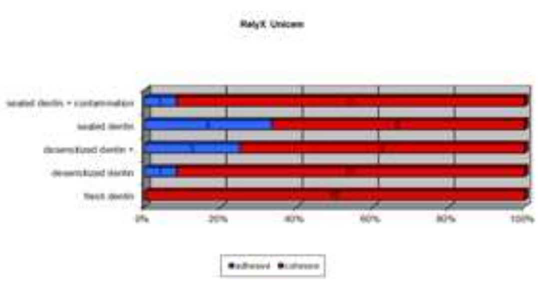


Fig.3. Debonding mode of specimens bonded with Variolink II (Series consisting of 12 specimens each).

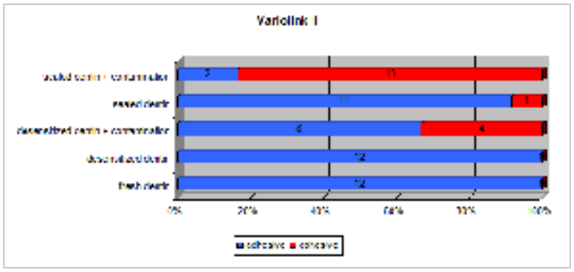


Fig.4. Debonding mode of specimens bonded with Panavia 21 (Series consisting of 12 specimens each).